Robert Schuman Centre

European Unemployment: Macroeconomic Aspects

Hysteresis and Ranges or Intervals for Equilibrium Unemployment

Rod Cross, Julia Darby
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EUROPEAN UNIVERSITY INSTITUTE, FLORENCE

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Hysteresis and Ranges of Intervals for Equilibrium Unemployment

ROD CROSS*, JULIA DARBY**
and
JONATHAN IRELAND*

*University of Strathclyde and ICMM
**University of Glasgow and ICMM

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Abstract

Natural rates of unemployment are often presented as single points. This paper points to analytical reasons why it is more plausible to think *of ranges* for equilibrium unemployment, with hysteresis operating as a equilibrium selection process. Empirical estimates of natural rates are usually derived from parameters estimated in regression equations. This means that there are statistical reasons for there being *confidence intervals* surrounding natural rate estimates. Some estimates of such confidence intervals are presented along with a tentative exploration of the explanatory power of hysteresis variables.

JEL Classification: El, E24, E31.

Natural rates of unemployment, in analytical models or in empirical estimates, tend to be presented as single points. This tends to mask the uncertainty surrounding both the models and the estimates. The present paper looks at two distinct types of reason why it might be more useful to think in terms *of ranges,* or in terms *of intervals,* for equilibrium unemployment.

The first consideration is analytical. If the underlying economic analysis allows for hysteresis, it is pointed out that the standard definition of the natural rate as depending on...... the structural characteristics of labour and commodity markets...... (Friedman 1968, p. 8) produces a *range of* possible values for equilibrium unemployment. Within this range, the particular unemployment equilibrium that will be realised will be determined by the history of the shocks affecting actual unemployment. Not all the *shocks* matter, as in the unit/zero root attempt to characterise "hysteresis" in linear models, only the non-dominated extremum values. Nominal as well as real shocks are potentially important, thus opening up the issue of whether the monetary neutrality axiom applies to equilibrium unemployment. This issue has important implications for unemployment policy.

The second type of reason for moving away from the single point characterisation of equilibrium unemployment is statistical in nature. Even if the natural rate hypothesis is accepted as true, natural rates or NAIRUs cannot be directly observed, but instead have to be estimated using statistical techniques. Natural rates or NAIRUs are usually estimated as non-linear functions of the parameters in regression equations. Uncertainty about parameter values inevitably means uncertainty about the derived natural rate or NAIRU estimates. Thus it makes sense to think in terms *of confidence intervals* for natural rate estimates. The size of the interval can have important implications for the appropriate stance of macroeconomic policy.

The paper is structured as follows. Section I points to some *of* the reasons why analytical models of natural rates have been amended to take "hysteresis" into account. The account here follows Amable, Henry, Lordon and Topol (1995) and Cross (1995) in pointing out that this literature has confused hysteresis with unit/zero roots or persistence. Section II outlines what hysteresis actually implies for equilibrium unemployment in terms of equilibrium selection within the feasible *range.* Section Ill deals with the confidence *intervals* surrounding estimates of natural rates or NAIRUs. Following the Fuhrer (1995), King, Stock and Watson (1995) and Staiger, Stock and Watson (1996a) work on US data, estimates of confidence intervals for natural rates or NAIRUs in Europe and elsewhere are presented. Cubic spline or mean shift specifications of natural rates are used, which possibly serve to present the natural hypothesis in its most favourable light. Finally, Section IV attempts some first tentative steps towards assessing the ability of hysteresis variables to explain unemployment.

I. The Natural Rate and Unemployment Persistence

The natural rate hypothesis of Phelps (1967) and Friedman (1968) initially bred two propositions: that management of monetary demand could not engineer

"... an arbitrary unemployment rate other than the natural level without sooner or later generating a continuing disequilibrium manifested by rising inflation or mounting deflation... and that the actual unemployment rate, though occasionally hit by shocks, is constantly homing in on the natural rate" (Phelps 1995 p. 15).

The background was not, as the commonly held wisdom has it, an empirical breakdown of the preceding Keynes-Phelps orthodoxy regarding unemployment and inflation, which "... was sailing on smooth waters, the object of much congratulation, rather like the *Titanic prior* to its collision with the fateful iceberg...". Instead

> "...the iceberg was the neutrality axiom of Lerner and Fellner. What made a collision of the Phillips curve with neutrality inevitable was that sooner or later someone - or some two - would provide one or micro-macro models of the Phillips curve, and with that the difficulty of maintaining that inflation was non-neutral, which the Phillips curve implies, would be exposed" (Phelps 1995, p. 17).

If aggregate demand can affect the actual but not the natural rate of unemployment, and if the natural rate is a strong attractor for actual unemployment, the question of what ***does*** determine the natural rate arises.

Determinants of the Natural Rate

Several traditions can be distinguished (see Blanchard 1990, Bean 1994 for surveys). In a first the natural rate is treated, by default, as *a constant. A* second sees the natural rate as a function of slowly changing variables such as *demographic structures.* In the Phelps (1968) labour turnover model, for example, a faster growth of the labour force leads to a higher natural rate because of the rising marginal cost of training. In a third tradition, which has dominated the literature on European unemployment, the variables driving the natural rate are mainly ***socio-economic*** in nature. This approach is based on the idea that unemployment serves to reconcile the price-setting behaviour by firms in product markets with the wages set or bargained in labour markets (Blanchard 1986). The focus has been on socio-economic pressures which serve to raise real wages, with unemployment benefit arrangements (UB), wage bargaining institutions (WB), minimum wages (MW) and employment protection measures (EP) being among the socio-economic variables seen as driving the natural rate (Layard, Nickell and Jackman 1991). A fourth approach is *the structuralist* account, based on intertemporal general equilibrium interaction between incentive wages in labour markets, firm-specific capital in the output markets and a largely neoclassical specification of asset markets (Phelps 1994). In this account the natural rate is endogenous with regard to real shocks, with real interest rates and exchange rates playing important roles in the transmission of the shocks. Among the shocks identified as important are the, albeit unintended, fiscal expansion in the US in the early 1980s and the hike in the real price of oil in 1979. Other real shocks which have been suggested as important in the recent literature are the opening up of economies such as China to international trade and shocks to technology (see OECD 1994, Pt. 1).

The third approach, focusing on socio-economic variables, has dominated the debate on why unemployment has risen in European countries (OECD 1994 for example). A typical "battle of the mark-ups" model (Layard, Nickell and Jackman, p. 378) is:

$$p\text{-}w = \alpha_0 - \alpha_1 u - \alpha_2(p - p^e) - \alpha_3(k - 1) \qquad (1)$$

$$w\text{-}p = \beta_0 - \beta_1 u - \beta_2(p - p^e) + \alpha_3(k - 1) + z \qquad (2)$$

where p is the price level, w is the money wage rate, u is the unemployment rate, p^e is the expected price level, k is the capital stock, 1 is the labour force, and all variables except u are in logs. Production technique and productivity effects are ruled out by the cancelling out of the (k-1) effects on prices and wages, and p^e is specified as derived from a unit root process for the rate of inflation, so $p^e = p_{-1} + \Delta p_{-1}$ and $p - p^e = \Delta^2 p$, where Δ is the difference operator. Defining the natural rate equilibrium as $p - p^e = \Delta^2 p = 0$ yields:

$$u^* = \frac{\alpha_0 + \beta_0 + z}{\alpha_1 + \beta_1} \qquad (3)$$

Thus the natural rate of unemployment (u*) is driven by a vector of wage pressure variables, z, which includes unemployment benefit arrangements (UB), minimum wages (MW), employment protection measures (EP) and wage bargaining institutions (WB). Any unexplained increases in price or wage push (α_0 and β_0), or reductions in price or wage responsiveness to unemployment (α_1 and β_1) would also serve to raise u*.

The European Evidence

Despite the official policy consensus that labour market reforms focusing on the z variables are the way to achieve sustainable reductions in unemployment, it is not clear that the z variables can explain the rise in European unemployment rates since the 1970s. For many of the European countries there has not been the upward shift in the z variables since the 1970s to match that in unemployment.

Indicators of unemployment benefit (UB) entitlements have risen in some countries but fallen in others (OECD 1996, p. 53). The OECD jobs Study analysis was that "...cyclical rises in unemployment, and the tendency for unemployment to persist in recovery periods, were often greater in countries with high benefit entitlements..." and that "...increases in unemployment which are due initially to a macroeconomic shock persist when benefits are high" (OECD 1994, Pt.II, p. 178). Thus the argument is not so much that UB entitlements have served to raise natural rates as that they have increased the persistence in the deviations of actual from equilibrium rates of unemployment.

If the assumption of competitive labour markets is dropped, the direction of the effects of minimum wage (MW) changes on u* becomes ambiguous. The conclusion of a recent survey of the evidence was that

> "...in most European countries, there has been little change in minimum wages relative to average earnings in the last 30 years ...it is hard to argue that the minimum wage has played a large part in the rise in European unemployment during this period" (Dolado, Kramarz, Machin , Manning, Margolis and Teulings 1996, p. 357).

Similar theoretical and evidential ambiguity surrounds the effects of some of the other z variables. Employment protection (EP) measures, for example, can tend to reduce both flows into, and flows out of, unemployment (OECD 1996, p. 45). And as far as wage bargaining (WB) institutions are concerned, unionisation rates fell in virtually all OECD countries, except the Nordic countries, in the 1980s (OECD 1994, Pt. 11, p. 10), and it was "difficult to detect beneficial effects of centralisation or coordination in pooled cross section time series studies on wage equations" (OECD 1994, Pt. II, p. 20).

The UK Case

Labour market reforms along the lines recommended for continental Europe have been actively pursued in the UK since 1979. If the "z" explanation of unemployment was correct, the UK should have experienced a fall in its natural rate. The official diagnosis is that this has happened: "...there seems to be accumulating evidence that in countries which have been active in pursuing labour market reform, such as the United Kingdom and New Zealand, structural unemployment rates have fallen" (OECD 1996, p. 56). This is not self-apparent.

Many of the ambiguities or uncertainties surrounding the influence of individual z variables on unemployment in continental Europe also apply to the UK (see Cromb 1993 for a survey). Cointegration tests have failed to identify vectors of z variables that cointegrate with UK unemployment (Darby and Wren-Lewis 1993). In 1979 UK unemployment stood at 5% on OECD definitions. At the end of 1996 unemployment remained substantially higher, at 8%, despite the labour market reforms in the intervening period. If the "z" explanation is correct UK unemployment should be able to fall substantially, say to a natural rate of 2-4%, without igniting a rise in inflation. Some commentators argue that this could be done, but this remains to be tested. At best the failure of UK unemployment to fall below the *status quo ante* the labour market reforms casts doubt on the strong attractor component of the natural rate hypothesis.

Blurring the Dichotomy

Not all academic economists have been convinced by the natural rate hypothesis:

> "...the way in which modern macroeconomists toss around the notion of a "natural rate of unemployment or employment" is a sort of intellectual scandal ...the coarseness of the definition and the weakness of the empirical results... suggest that we are in the presence of something that is believed for extra-scientific reasons" (Solow 1987b, p.183).

At the policy level, the UK Chancellor of the Exchequer 1983-89 was

> "...extremely suspicious of analysis in terms of... equilibrium unemployment rates ... they are in practice extremely nebulous magnitudes, and estimates are contradictory and subject to huge variations, even when made by the same economist... since we do not have much idea of what the NAIRU is, I do not find it a helpful concept..." (Lawson 1992, pp. 230, 435).

One of the key areas of concern has been the strong dichotomy between the actual and equilibrium rates of unemployment implied by the natural rate hypothesis. If the determinants of the natural rate, such as the z variables, had been able to explain the upward shifts in European unemployment rates in the 1980s and 1990s this dichotomy could have been maintained. The fact that actual unemployment rates have remained higher than plausible estimates of natural rates for protracted periods without the accompaniment of falling inflation, however, has led investigators to amend the natural rate hypothesis to allow shocks affecting actual unemployment to influence the natural rate or NAIRU over some "short term". This means, at least in some short term, that actual unemployment can serve as an attractor for equilibrium unemployment.

> "The image of unemployment given... was one of aggregate demand-driven fluctuations in actual unemployment around an equilibrium that itself moved in response to movements in z... this dichotomy... did not fit the experience of the 1980s, in which a sharp, aggregate demand-induced increase in unemployment had been followed by an increase in equilibrium unemployment... this dichotomy had to be abandoned for progress to be made" (Blanchard 1990, p.72).

The reasons for suspecting that shocks to actual unemployment may influence equilibrium unemployment are usually described as relating to the presence of "hysteresis". The effects of shocks to actual unemployment or output on "structural characteristics" such as the balance of insiders and outsiders in the labour force (e.g. Blanchard and Summers 1988), long-term unemployment (e.g. Layard, Nickell and Jackman 1991) or stocks of physical capital (eg. Blanchard 1990) are some of the sources of "hysteresis" that have been investigated. In this literature "hysteresis" takes two distinct forms. The first is *persistence,* in which the natural rate hypothesis is retained as a long-run attractor, but supplemented by a short-run natural rate or NAIRU which is affected by shocks to actual unemployment. In the second *zero/unit root case* the natural rate hypothesis no longer applies, the equilibrium rate of unemployment instead evolving in response to all of the shocks, real or nominal , affecting actual unemployment.

"Hysteresis" as Persistence

In one well-known account "hysteresis" effects arise because increases in actual unemployment tend to be associated with a fall in the rate of outflow from unemployment. This, unless special provision is made once an unemployment spell reaches a critical length, leads to more people experiencing long spells of unemployment, say longer than a year. The long- term unemployed are seen as experiencing an actual or perceived decline in productivity, or propensity to search for work, and can become, in effect, disenfranchised from competing for job vacancies. This change in the "'structural" characteristics of the unemployed will in general depend on the dynamics of actual unemployment. In simplified form this effect can be captured by adding Δu terms to the price and wage equations (1) and (2) above (see Nickell 1987 and Layard and Nickell 1987). In other words $\Delta u > 0$ is accompanied by higher long-term unemployment, and less downward pressure on prices or wages for any given level of unemployment; and vice versa for $\Delta u < 0$. Re-writing (1) and (2) gives:

$$p\text{-}w = \alpha_0 - \alpha_1 u - \alpha_{11}\Delta u - \alpha_2(p-p^e) - \alpha_3(k-1) \tag{4}$$

$$w\text{-}p = \beta_0 - \beta_1 u - \beta_{11}\Delta u - \beta_2(p-p^e) + z + \alpha_3(k-1) \tag{5}$$

Imposing the $p - p^e = \Delta^2 p = 0$ condition, but not $\Delta u=0$, yields:

$$us^* = \frac{(\alpha_1 + \beta_1)u^* + (\alpha_{11} + \beta_{11})u_{-1}}{\alpha_1 + \beta_1 + \alpha_{11} + \beta_{11}} \tag{6}$$

Thus the short-run natural rate us* depends on u*, and hence on z, but also on the previous period's actual unemployment u_{-1}. The difference equation for actual unemployment underlying (6) is:

$$u_t = A + Bu_{t-1} + CZ_t - D\epsilon_t \tag{7}$$

where $A = (\alpha_0+\beta_0)(\alpha_1+\alpha_{11}+\beta_1+\beta_{11})^{-1}$
$B = (\alpha_{11}+\beta_{11})(\alpha_1+\alpha_{11}+\beta_1+\beta_{11})^{-1}$
$C = (\alpha_1+\alpha_{11}+\beta_1+\beta_{11})^{-1}$
$D = (\alpha_2+\beta_2)(\alpha_1+\alpha_{11}+\beta_1+\beta_{11})^{-1}$
and $\epsilon = p\text{-}p^e = \Delta^2 p$

The particular integral of (7) defined by the natural condition $p\text{-}p^e = \Delta^2 p = 0$ is:

$$u_t^* = \frac{A + Cz_t}{1 - B} = \frac{\alpha_0 + \beta_0 + z}{\alpha_1 + \beta_1} \tag{8}$$

Thus convergence onto the long-run natural rate will occur if $\beta < 1$. If $\alpha_1 + \beta_1 > 0$ this condition will be satisfied. This is the case assumed to hold in the Layard-Nickell model:

> " ...there is short-term "hysteresis", in the sense that past events affect the current short-run NAIRU - but there is no long-term "hysteresis": there is a unique long-run NAIRU... in the end the unemployment rate always reverts" (Layard, Nickell and Jackman 1991, p.10).

If the level effects of unemployment, α_1 and β_1, are small relative to the rate of change of unemployment effects, α_{11} and β_{11}, the tendency to converge on the natural rate equilibrium will be at best weak (see Alogoskoufis and Smith 1991 and Manning 1993 for evidence to this effect). In fact a key reason for wide confidence intervals for natural rate estimates discussed in Section III of this paper is that the level effect of unemployment on prices or wages is not particularly well-determined (Staiger, Stock and Watson 1996a). Over the time spans of 30 years or so over which natural rate models are usually estimated unemployment tends to appear to be an I(1) variable. To date the various specifications of vectors of z variables tried have failed to identify cointegrating vectors for actual unemployment (Darby and Wren-Lewis 1993). It may be that the real shocks invoked in the Phelps (1994) approach prove able to supplement the z variables and yield cointegration attractors for actual unemployment, but this remains to be shown.

Zero/Unit Root "Hysteresis"

The above persistence case is often referred to as "weak hysteresis" in contrast to the "full hysteresis" case of zero roots in the underlying linear differential equations, or unit roots in the underlying difference equations (Giavazzi and Wyplosz 1985 and Wyplosz 1987, for example). Taking the discrete time case, the unit root case corresponds to B = 1 in (7) above, which will occur when the level effects of unemployment are insignificant, so $\alpha_1 + \beta_1 = 0$. In this case imposing $p_T = p^e_T$ yields

$$u^*_T = u_0 + AT + C\sum_{i=0} z_{T-i} + D\sum_{i=1} \epsilon_{T-i} \tag{9}$$

Thus in this unit root case the "equilibrium" rate of unemployment depends on all the past shocks to unemployment. Taken literally this means that the memory of the system is Methusalehesque and unselective, shocks in the distant past having as much impact as more recent shocks, and small shocks having the same effects, *pro rata,* as large shocks. This is implausible. The unit root (or zero unit) case also has the property that two shocks of equal size but opposite sign will see unemployment return to the *status quo ante* the shocks. As the next section shows, systems with hysteresis do not have these properties.

II. Hysteresis

The term hysteresis comes from the Greek "to be late, or come behind". The term was first coined for application to scientific explanation by the physicist Ewing (1881) to refer to effects (in terms of magnetisation) that remain after the initial cause (the application of a magnetising force) is removed. Such effects have subsequently been discovered or invoked in relation to a wide array of physical, biological and social phenomena. A general account of hysteresis as a systems property has been provided in Krasnosel'skii and Pokrovskii (1989). The key elements required to produce hysteresis are some form *of non-linearity* in the way the elements in a system respond to shocks; and *heterogeneity* in the elements and therefore in their responses to shocks.

The key implications of hysteresis are *remanence,* in that the application and reversal of a shock will not be followed by a return to the *status quo ante*; and a *selective memory,* in which only the non-dominated extremnum values of shocks remain in the memory bank, dominated extremum values being wiped (see Cross 1993 for a general account of hysteresis).

Standard economic analysis assumes that economic equilibria are *homeostatic,* in that the reversal or removal of a temporary shock will be accompanied by a return to the initial equilibrium. The issue of hysteresis raises the question of whether this assumption holds in economic systems. Marshall (1890, pp. 425-6) thought that this assumption was likely to be violated in actual market processes, citing the effects of the shock to the supply of cotton during the American Civil War as an example. At a more aggregate level Keynes (1934) answered the question “are economic systems self-adjusting?” in the negative. If temporary shocks can have permanent effects economic equilibria become characterised by *heterostasis*, there now being a range of possible equilibrium values, with the actual equilibrium realised being determined by the temporary shocks experienced.

Hysteresis thus involves stronger properties than those conveyed by the use of the term to describe persistence or zero/unit roots. In the persistence case the natural rate equilibrium is unchanged by shocks affecting actual unemployment, whereas hysteresis implies that each new extremum value of the shocks experienced will lead to a new unemployment equilibrium. In the zero/unit root case all the shocks experienced shape the equilibrium, whereas hysteresis involves only the non-dominated extremum values of the shocks counting in the equilibrium selection process.

In the policy literature the key distinction is usually perceived as being between structural and actual unemployment:

> " ...economic analysis generally distinguishes between the actual unemployment rate prevailing at any time, and the "natural" (or "structural") unemployment rate (OECD 1994 Pt.1, p. 66).

The presence of hysteresis implies that temporary shocks can change the structural dynamics which help determine equilibrium unemployment (see Amable, Henry, Lordon and Topol 1995). Thus, in contrast to the natural rate hypothesis, the shocks associated with the peaks and troughs of actual unemployment are themselves part of the process determining equilibrium unemployment.

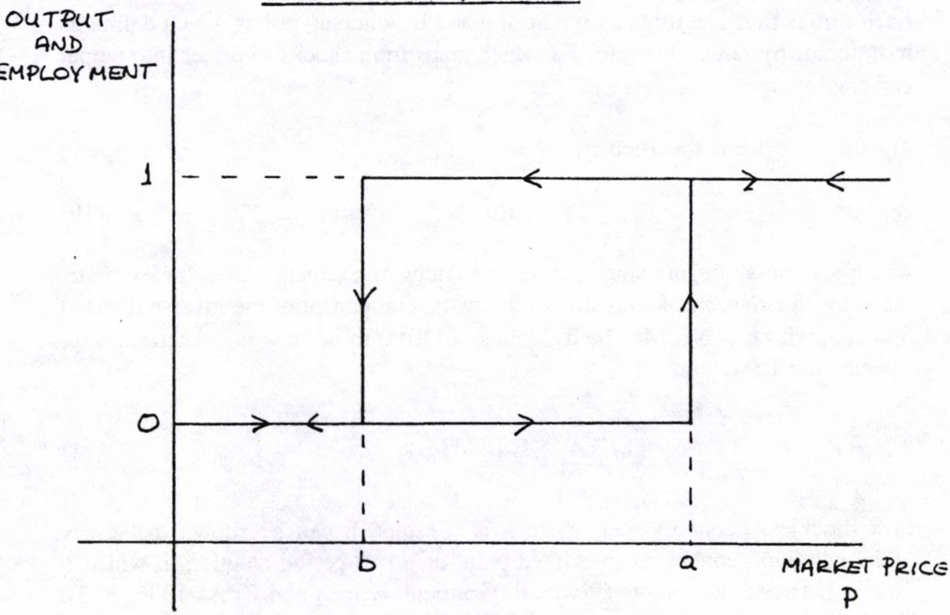
An Illustrative Model

The simplest form *of non-linearity* in the Krasnosel'skii and Pokrovskii (1989) hysteresis analysis is the piecewise linear case analysed in Mayergoyz (1991). This framework is well suited to micro foundations based on discontinuous adjustment (Cross 1994). The presence of fixed costs of adjustment in the form of, for example, the sunk costs associated with investment or market entry (Dixit and Pindyck 1994), including entry into export markets (Amable, Henry, Lordon and Topol 1994), implies the existence of separate triggers for upward and downward adjustment. The following exposition is based on Piscitelli, Grinfield, Lamba and Cross (1996), which analyses market entry and exit under sunk costs in a Dixit-Pindyck framework.

The market has M potential suppliers. The number of active firms is N. When active, that is in the market, each firm produces one unit of output and employs one unit of labour. When out of the market firms produce zero output and employ zero units of labour. Each firm faces sunk costs of market entry, the i^{th} firm requiring a market price of $p \geq a$ to induce entry and a price of $p \leq b$ to induce exit. Figure 1 illustrates the two switching points. In the range $b < p < a$ the firm will either be active or inactive depending on its previously acquired propensity, which turns on whether this range has been approached from above or below.

FIGURE 1

SWITCHING POINTS



Heterogeneity is introduced by allowing the a and b switching points to differ between firms:

> "...different firms have different technologies or managerial abilities... historical accidents may leave different firms with stocks of capital that are differently situated relative to their action thresholds... then they will have different action thresholds ..." (Dixit and Pindyck 1994, p. 421).

Each firm is thus identified by a pair of a and b switching points which define its hysteron or hysteresis operator F_{ab} which maps from shocks to prices into output and employment.

The market price is specified as:

$$p_t = x_t f(q_{t-1}) \tag{10}$$

where x is an aggregate shock, to interest rates or exchange rates for example, faced by all firms, and f(q) is the deterministic component of the inverse demand function, with $q_{t-1} \cong N_{t-1}/M$. The dynamics of (10) turn on how p_{t+1} determines q_{t+1}, which can be written:

$$q_{t+1} = \frac{1}{M} \sum_{i=1}^{M} F_{ab}\left[x_{t+1} f(q_t)\right] \tag{11}$$

In a shockless economy, i.e. where x is constant, it can be shown that every initial condition converges to a fixed point or a two-period solution in which q swings between two points (Piscitelli, Grinfield, Lamba and Cross 1996, p. 3). The interesting question is what happens in an economy with shocks.

Consider the effects of a sequence of aggregate shocks that generates the price illustrated in Figure 2. As the price rises to p_1 firms with $a \leq p_1$ enter the market and employ labour, as the price falls to p_2 firms with $b \geq p_2$ leave the market and cease to employ labour, and so on. The division between active and inactive firms is illustrated in Figure 3, which uses the Mayergoyz (1991) half-plane diagram in which each firm is represented by its (a, b) switching characteristics. The (a_0, b_0) vertex of the triangle is determined by boundary conditions. The distribution of firms within the triangle can be seen as depending, *inter alia*, on the "structural characteristics of labour and commodity markets", such as the "z" variables discussed in Section I of this paper, stressed in the natural rate literature. Thus a more favourable set of "z" characteristics would tend to shift the (a, b) values south-westwards in the triangle, so yielding higher activity and employment levels for any given set of aggregate shocks.

FIGURE 2

A SEQUENCE OF SHOCKS

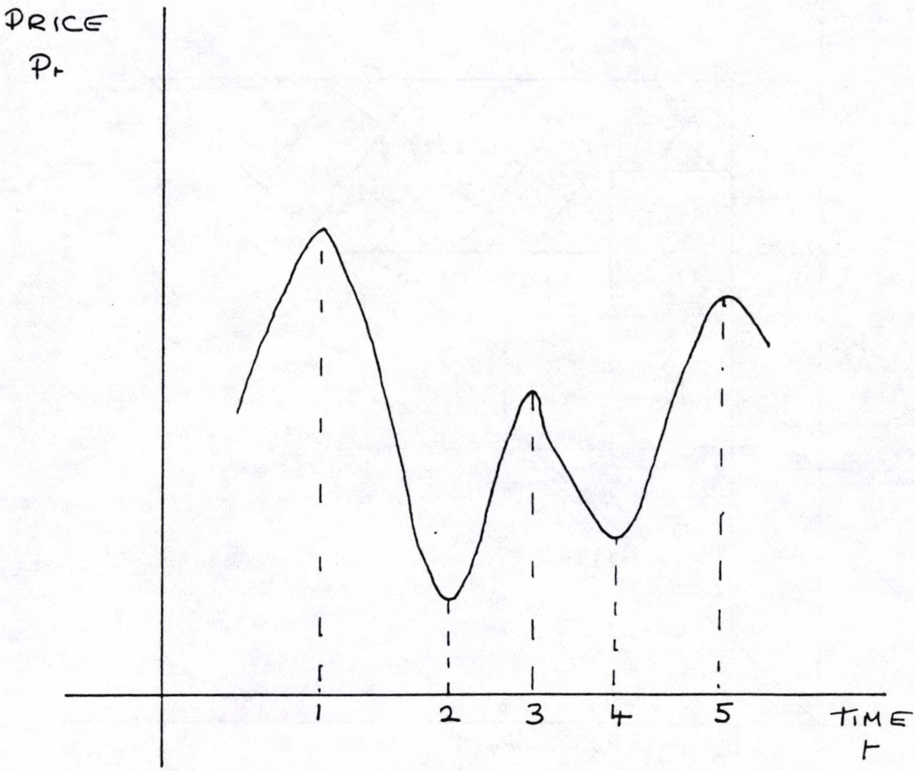
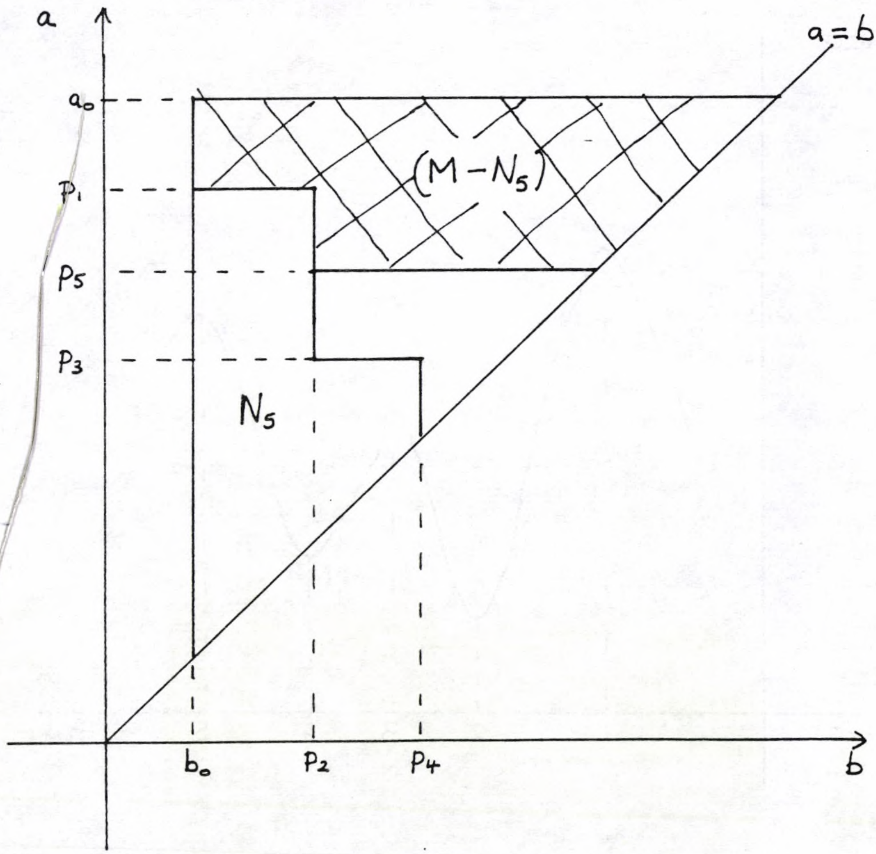


FIGURE 3

STAIRCASE PARTITION BETWEEN ACTIVE AND INACTIVE FIRMS



N ≡ ACTIVE FIRMS

(M − N) ≡ INACTIVE FIRMS

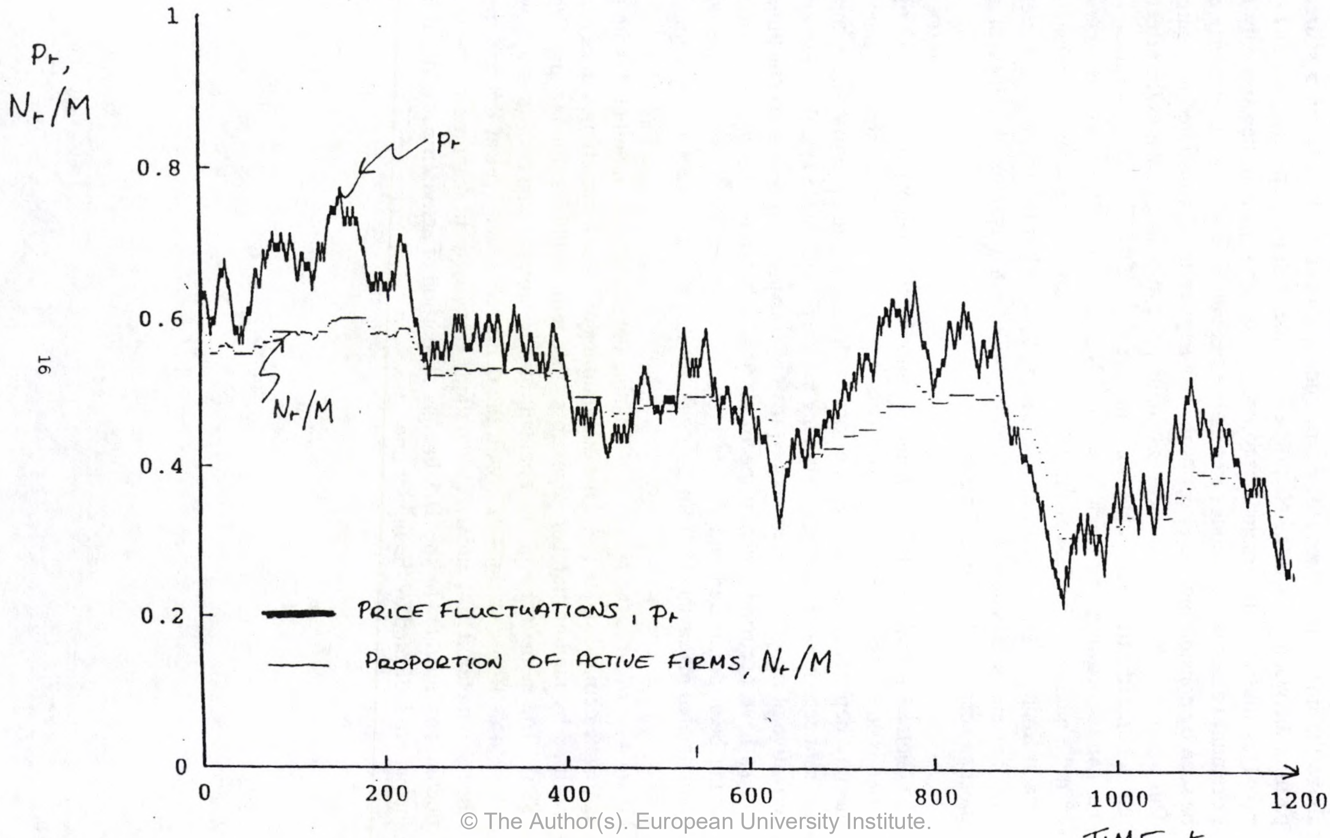
Referring to Figure 3, the rise in price to p_1 serves to create a horizontal partition between the N, active firms below the p_1 line, and the $(M-N_1)$ inactive firms above the line. The subsequent p_2, p_3 and p_4 shocks then trace out a staircase partition between N_4 and $(M-N_4)$, the coordinates being (p_1, p_2), (p_3, p_2) and (p_3, p_4). This illustrates the memory property of systems with hysteresis: only the extremum values of the shocks experienced count. The wiping-out property can be seen by considering the effect of the rise in price to p_5, illustrated in Figure 2. This dominates the previous local maximum price at p_3 and so wipes the effect of this dominated extremum value from the memory bank. Thus the coordinates of the staircase partition between N and (M-N), (p_3, p_2) and (p_3, p_4) are removed from the memory. This leaves the new staircase partition between the unhatched area in figure 3, N_5, and the hatched area, $(M-N_5)$. Thus the memory of systems with hysteresis is selective: only the non-dominated extremum values of the shocks experienced retain an effect.

The contrast with the unit root characterisation of the memory properties of time series is interesting. Unit root tests characterise time series as short or long in memory depending on whether the root is closer to zero or **unity,** the extreme unit root case implying an infinitely-long memory. With hysteresis the memory is derivative of the pattern of shocks. If the major expansionary and contractionary shocks have occurred recently the memory will be short, the previous shocks having been dominated and therefore eliminated from the memory. Otherwise undominated major shocks from the more distant past can impart a long memory.

Figure 4 reproduces the results of simulating the model in (10) and (11), with the aggregate demand shock x and the distributions of a and b switching values being specified by random number generators (Piscitelli, Crinfield, Lamba and Cross 1996). The non-stochastic component of the inverse demand function was specified as $f(q_t) = \alpha(\beta q_t + 1)^{-1}$, with the α intercept being set at 0.8 and the p slope parameter at 1.4, and 1,200 iterations were used. In response to the price fluctuations indicated by the dark line the proportion of active firms N/M follows the pattern indicated by the lighter line.

FIGURE 4

PRICE FLUCTUATIONS AND THE PROPORTION OF ACTIVE FIRMS



Ranges for Equilibrium Unemployment

It is, of course, a major step to move from the simple model of hysteresis above to the equilibrium rate of unemployment. The model, however, does offer some guidelines. The "structural characteristics of labour and commodity markets" or "z" variables stressed in the natural rate literature can be seen as affecting the (a, b) values of firms. Thus a more favourable set of z characteristics would tend to reduce the a and b values of firms , making firms more likely to be active and employing labour for any given sequence of aggregate shocks, thus reducing the rate of inactivity or "unemployment" (M-N)/M. The innovation is that the sequence of shocks experienced, in the form of the non-dominated extremum values, also shapes the rate of inactivity or unemployment. The implication is that, for any given set of "z" characteristics, there will be a range of feasible equilibrium unemployment rates. Each new extremum value of the shocks will, by changing the partition between active and inactive firms, change the equilibrium unemployment rate.

The inflation-unemployment interaction suggested by this hysteretic equilibrium can be written as:

$$p_t - p_t^e = \Delta^2 p_t = F\left[u_t - uh_t^*\right] \qquad (12)$$

$$u_t = g\left[z_t, x_t\right] \qquad (13)$$

$$uh_t^* = f\left[z_t, h_t(x)\right] \qquad (14)$$

Equation (12) follows the natural rate hypothesis except in specifying the equilibrium as hysteresis-haunted; equation (13) is standard in saying that actual unemployment depends on the contemporary value of the aggregate shock x as well as on the z variables; and equation (14) specifies the hysteresis equilibrium for unemployment, uh*, as depending on a hysteresis index of the past non-dominated extremum values of the shocks h(x), as well as on z.

To illustrate how this system works consider the sequence of aggregate shocks, to interest rates or exchange rates say, illustrated in Figure 5. Whether or not a particular interest rate or exchange rate is expansionary or contractionary depends on z. The horizontal line on the diagram is thus conditioned on a particular value of z, $\bar{z}$. A less favourable set of z characteristics, z^+, would shift the horizontal line upwards, making any given interest rate or exchange rate more contractionary or less expansionary; and vice-versa for a more favourable shift in z characteristics to z^-.

Figure 6 illustrates the implications for unemployment and inflation of the shocks given in Figure 5. The contractionary shock reaching a trough in period 2 sees unemployment rise from 1 to 2. The actual is above the equilibrium rate of unemployment, so the rate of inflation falls. As the contractionary shock fades in the face of real balance effects, the system does not retrace its steps back to the original equilibrium, as the natural rate hypothesis would imply, but instead reverts to a higher equilibrium unemployment rate in period 3: the extremum value of the shock experienced in period 2 remains in the memory bank. The expansionary shock in period 4 sees unemployment fall below the equilibrium rate, the rate of inflation rises, which stimulates adverse real balance effects. Unemployment rises to a new equilibrium rate in period 5, which is lower than the preceding equilibrium rate because the period 4 shock is retained in the memory bank. And so on. Take this economy through a further sequence of shocks and a range of equilibrium unemployment rates is traced, corresponding to the intersections with the vertical axis.

The position of the vertical axis itself in Figure 6 is conditioned on a particular value of z, $\bar{z}$. If the z characteristics move favourably to z^- the equilibrium rates of unemployment would be lower for any given x shocks, and vice-versa if there are unfavourable developments to z^+.

Thus in an economy exposed to shocks there is a range of possible values for equilibrium unemployment. Rather than leaving the equilibrum indeterminate, the hysteresis hypothesis specifies the specific sub-set of the values of the shocks that determine the realised equilibrium. The "z" variables invoked by the natural rate hypothesis are also included, and would be the sole determinants of equilibrium unemployment in a shockless economy. The implications for policy in a world of shocks, however, are substantially different, macro policy measures being reinstated as having potentially lasting influences on unemployment as well as on inflation.

FIGURE 5

CONTRACTIONARY AND EXPANSIONARY SHOCKS

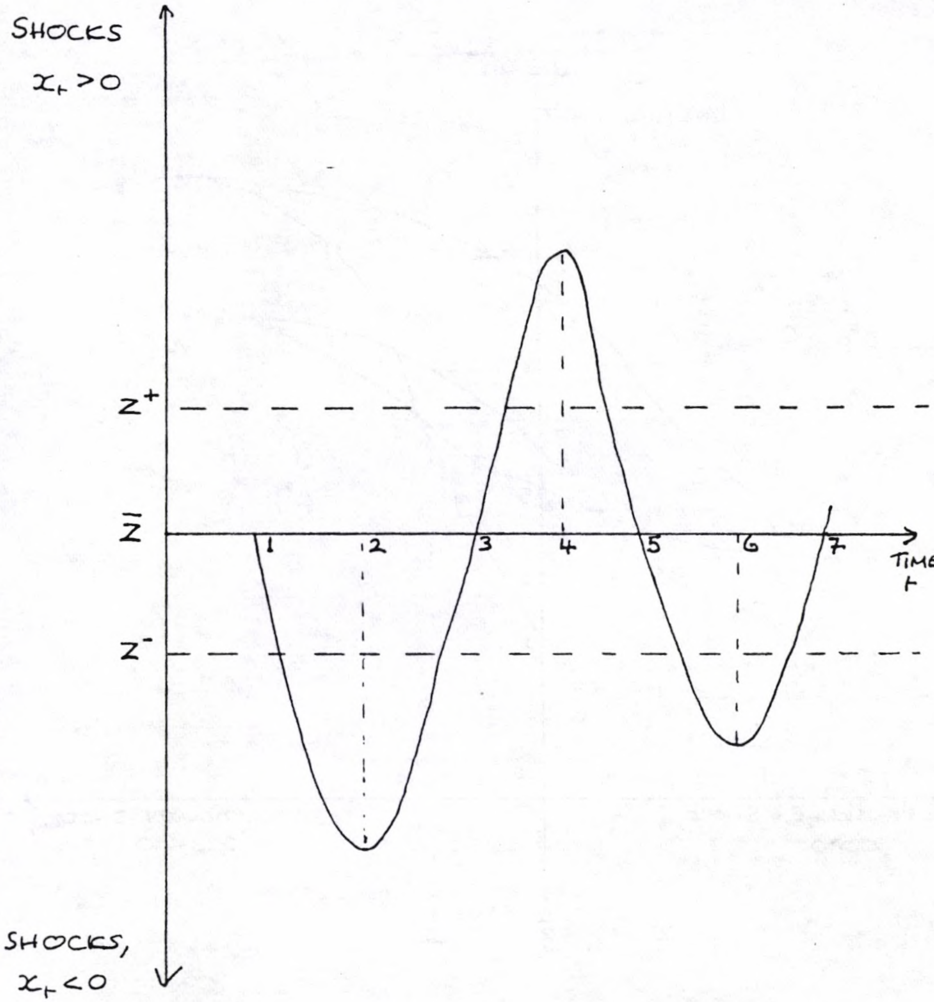
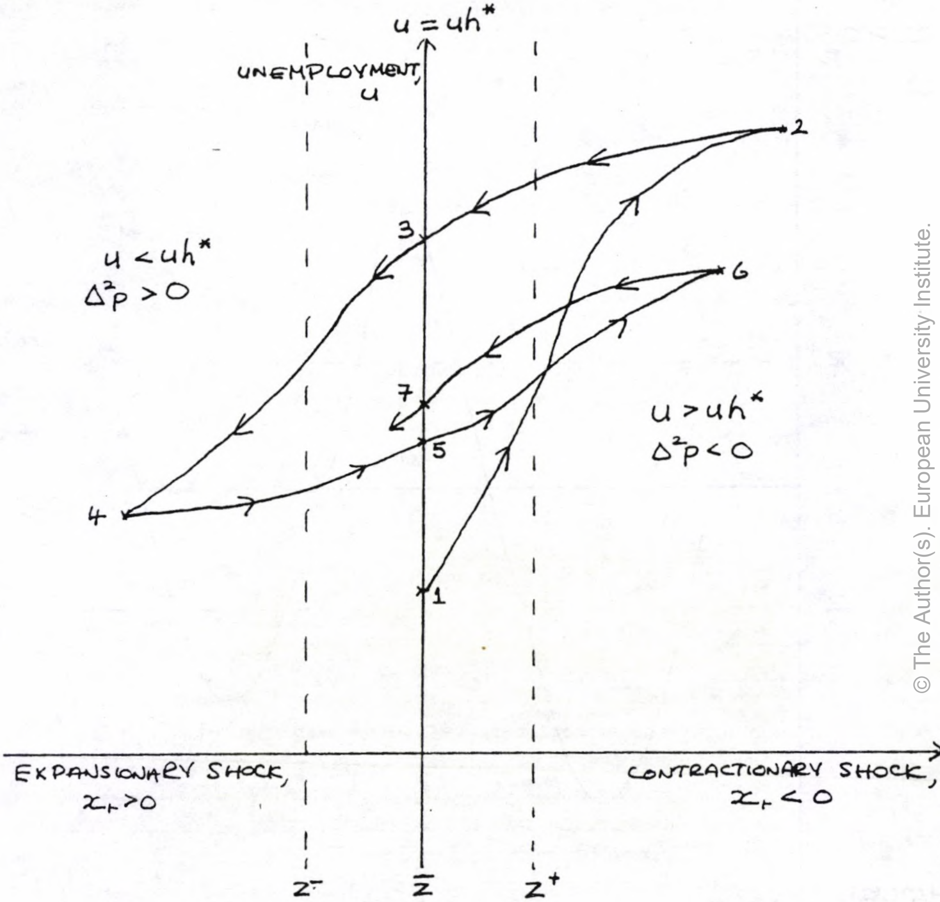


FIGURE 6

HYSTERESIS AND RANGES FOR EQUILIBRIUM UNEMPLOYMENT



III. Some Confidence Intervals

The propensity of different models to yield different estimates of natural rates or NAIRUs is reasonably well known. For the UK 1988-90, for example, the NAIRU estimates ranged from 3.5% to 8.1%, compared to actual unemployment, on a claimant definition, of 6.8% (Cromb 1993). Some of the differences arise from different specifications of the "z" variables, or of their quantitative impact. Another difference is that between "structural" estimates of NAIRUs, derived from the z variables, and "reduced-form" estimates based on equations such as:

$$u^* = u + \alpha_1\Delta^2 p + \alpha_2\Delta u - \alpha_3 tb \tag{15}$$

where *tb is* the trade balance (Layard, Nickell and Jackman 1991).

A source of uncertainty that is less well documented, however, is that arising within any given model of the natural rate or NAIRU. A natural rate estimate based on a "battle of the mark ups" model, such as in equations (1) - (3) above, is derived from point estimates of coefficients in regression equations. The point estimates of the coefficients are, of course, subject to confidence intervals, so this source of uncertainty will be transmitted to the natural rate estimate. The natural rate often appears as a ratio of regression coefficients, so the confidence interval surrounding the derived natural rate estimate cannot be immediately deduced from the diagnostic test statistics usually reported.

In the recent literature Fuhrer (1995) and Staiger , Stock and Watson (1996a) estimated confidence intervals for natural rates or NAIRUs in the US. Two methods have been used. Fuhrer (1995) used the "delta" method , which is a general approach to constructing standard errors for non-linear functions of parameters. A Taylor series expansion is used to provide a linear approximation to the underlying non-linear function, on the basis that the linear approximation will be asymptotically normally distributed. Staiger, Stock and Watson (1996a) found in Monte Carlo simulations, however that the finite sample distributions of estimated NAIRUs were non-normal. The NAIRU is often estimated as a ratio of coefficients, and distributions of ratios of random variables are usually non-normal, bi-modal for example. Thus there seem to be good reasons for following Staiger, Stock and Watson (1996a) in using "Fieller's method" for estimating confidence intervals, even though this procedure is very expensive in terms of computer time.

The intuition under the "Fieller method" can be explained by considering the following natural rate specification:

$$\Delta^2 p_t = \sum_{i=1} \gamma_i (u_{t-i} - u^*) + \in_t \tag{16}$$

Where $\Delta^2 p_t$ is the change in the rate of inflation, u is actual unemployment, u* is a fixed natural rate and $\in$ is an error term. A more general specification would add control variables and lagged dependent variables to the right-hand side of (16). Estimation of a confidence interval for u* is non-standard because u* enters non-linearly as $-\sum_{i=1} \gamma u^*$. For this reason it is more straightforward to estimate:

$$\Delta^2 p_t = \overline{u} + \sum_{i=1} \gamma_i u_{t-i} + \in_t \tag{17}$$

where $\overline{u} = -\sum_{i=1} \gamma_i u^*$. From (17) the natural rate can be estimated as $u^* = \frac{-\overline{u}}{\sum_{i=1} \gamma_i}$ using OLS estimates. To construct a confidence interval around this u* estimate the "Fieller method" employs a trial-and-error procedure. The 95% confidence interval around both sides of u* is the set of u* values that cannot be rejected as true using a 5% hypothesis test. This set is constructed by selection of trial values of u*. So a trial value of u*=8%, for example, is selected and (17) is estimated using (u_{t-i} - 8%) rather than u_{t-i} as regressors. If u*=8% is true, the value of the intercept in (17) would be zero, so the hypothesis u*=8% is tested indirectly by testing for $\overline{u}$=0 in:

$$\Delta^2 p_t = \overline{u} + \sum_{i=1} \gamma_i (u_{t-i} - u^*) + \in_t \tag{18}$$

This procedure is then repeated for all possible values of u*, the 95% confidence interval then being defined as the set of u* values that yield intercept estimates for $\overline{u}$ that are insignificantly different from zero at the 5% level.

Specifying the Natural Rate

Staiger, Stock and Watson used a variety of specifications of the US natural rate. A distinction can be drawn between statistical specifications for u_t* and economic theory specifications, such as those using the "z" variables discussed in Section I of this paper. To date we have generated results for two of the statistical specifications: (i) a constant natural rate, and (ii) a cubic spline representation.

The (i) constant u* specification is self-explanatory. In the (ii) cubic spline specification $u_t^*=f(S_t)$ where S_t is specified as a cubic function with two equidistant knot points. Details of the econometric specifications are as given in Staiger, Stock and Watson (1996a).

The data set used is for quarterly unemployment rates and CPI inflation in selected OECD countries for 1960:1-1995:3 taken from the OECD Business Sector Database and Main Economic Indicators. The procedure was to replicate the Staiger, Stock and Watson estimates for the US, and then generate results for other OECD countries. The rate of inflation Δp_t was defined as the four-quarter change in consumer prices, and the unemployment rates u_t are based on the OECD definition. The following abbreviations identify the countries concerned: USA - United States of America; CAN - Canada; JPN - Japan; DEU - West Germany; FRA - France; ITA - Italy; GBR - United Kingdom; IRE - Ireland; ESP - Spain; AUT - Austria; SWE - Sweden; AUS - Australia; and NZL - New Zealand.

Constant Natural Rates

Chart 1 graphs the unemployment rates and constant NAIRUs estimated for the various countries, and Chart 2 gives a scatter plot between Δ2pt and the implied (u_{t-1} -u*) deviations. it is reasonably clear that a constant NAIRU is not a very plausible hypothesis for the countries in question, with the possible exception of the US. The visual impression is confirmed by the confidence intervals reported in Table 1. The 95 % confidence interval for the US natural rate of 4.424 % - 8.120% is in line with the Staiger, Stock and Watson results. For the selection of other countries reported, however, the 95% intervals lie outside the possible range for unemployment. The 80% confidence intervals reported indicate that, even at this confidence level, the size of the NAIRU intervals is indeed large. The underlying reason for such large intervals is reflected in the coefficient on lagged unemployment, γ_1, which is not particularly well determined, even in the case of the US.

Cubic Spline Natural Rates

Chart 3 graphs the cubic splines for the natural rate estimated for the various countries. The splines were structured as having two equidistant knots, with the other dimensions data determined. The visual impression is that the splines are somewhat more plausible than the constant natural rate specifications. Chart 4 graphs $\Delta^2 p_t$ against the $(u_{t-1} - u^*_{t-1})$ terms implied by the splines. For some of the countries the negative correlation expected between $\Delta^2 p_t$ and $(u_{t-1} - u^*_{t-1})$ is apparent, but the visual impression is that there are a wide range of intercepts for $\Delta^2 p_t = 0$ that are consistent with the data. This visual impression is confirmed by the 95% confidence intervals for a selection of countries reported in Chart 5 and Table 2. To allow for the fact that the spline will not be well defined at the end points of the sample period, the NAIRUs and associated confidence intervals reported in Table 2 are for 1990:1.

Discussion

As suggested in Section I of this paper, it is not clear that the "z" variables usually invoked by the natural rate hypothesis are able to explain the sustained upward shifts in unemployment experienced in many European countries and elsewhere since the 1970s. Statistical representations, such as the cubic splines reported earlier, are able to mimic at least some of the putative upward shifts in natural rates of unemployment, but beg the question of whether the variables of the z type stressed in the natural rate hypothesis have been the driving force. Arguably, statistical representations such as splines present the natural rate hypothesis in a favourable light.

Despite this, the confidence intervals for the natural rates or NAIRUs implied by the statistical representations are quite wide. Thus arguments such as that macroeconomic policy needs to be restrictive because unemployment is below the natural rate need to be treated with a degree of caution. Even if the natural rate hypothesis is taken to be true, within the confines of any specific model there is a large degree of uncertainty as to what the natural rate actually is.

IV. Some Hysteresis Indines

Given the various uncertainties surrounding the natural rate hypothesis and estimates of natural rates, it is worth investigating alternative hypotheses, such as that of hysteresis in equilibrium unemployment. The analytical properties of systems with hysteresis, as discussed in Section II of this paper, are reasonably well known, but empirical applications to economic time series are still in the early stages of development.

Some of the steps required to produce estimates of hysteresis-haunted equilibrium rates of unemployment can be illustrated by referring to Figure 3 above, in which the equilibrium unemployment rate uh* is approximated by (M-N)/M. To estimate uh* in this framework requires calculation of the area below or above the staircase partition between active firms, N, and inactive firms, (M-N).

Step 1: this requires specifying the boundary conditions (a_0, b_0) which determine the size of the right-angled triangle for M in Figure 3. In applications to physical systems the boundary conditions often correspond to obvious physical limits, such as magnetic saturation (Mayergoyz 1991). In economic systems the boundary conditions are less obvious. In Chart 6 the boundary points were determined as the global maximum and minimum values taken by unemployment over the sample period. More generally the boundary conditions would be estimated as free parameters.

Step 2: this involves specifying the distribution of the (a, b) switching points within Figure 3 , that is the Preisach function (Mayergoyz 1991). In Chart 6 it is assumed that the (a, b) switching points are uniformly distributed. Ideally the (a, b) distributions would be specified on the basis of cross-sectional evidence , or at least allowed to vary with the "z" structural characteristics, as discussed in Section II.

Step 3: this involves identifying shock variables to determine the vertices of the staircase partition in Figure 3. Experiments with time series for real exchange rates and real interest rates have generated hysteresis indices, h(x), for these x shocks that are, by and large, plausible (Piscitelli 1997). To date, however, the h(x) results are not available for the 1960- 1995 period. Chart 6 reports time series for h(u), that is hysteresis indices for actual unemployment. This begs the questions of how the h(x) variables shape h(u).

Step 4: the final step involves writing a programme for the hysteresis indices, h(x) and h(u), which is presented in Piscitelli (1997).

Chart 6 graphs the h(u) indices generated for the US, UK, Germany, France, Italy and Japan, along with the time series for actual unemployment rates, u. The broad pattern of the h(u) indices is not implausible, but this represents no more than a preliminary and tentative first step towards investigating the explanatory power of the hysteresis hypothesis for equilibrium unemployment.

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CHART 1: UNEMPLOYMENT RATES AND CONSTANT NAIRUs

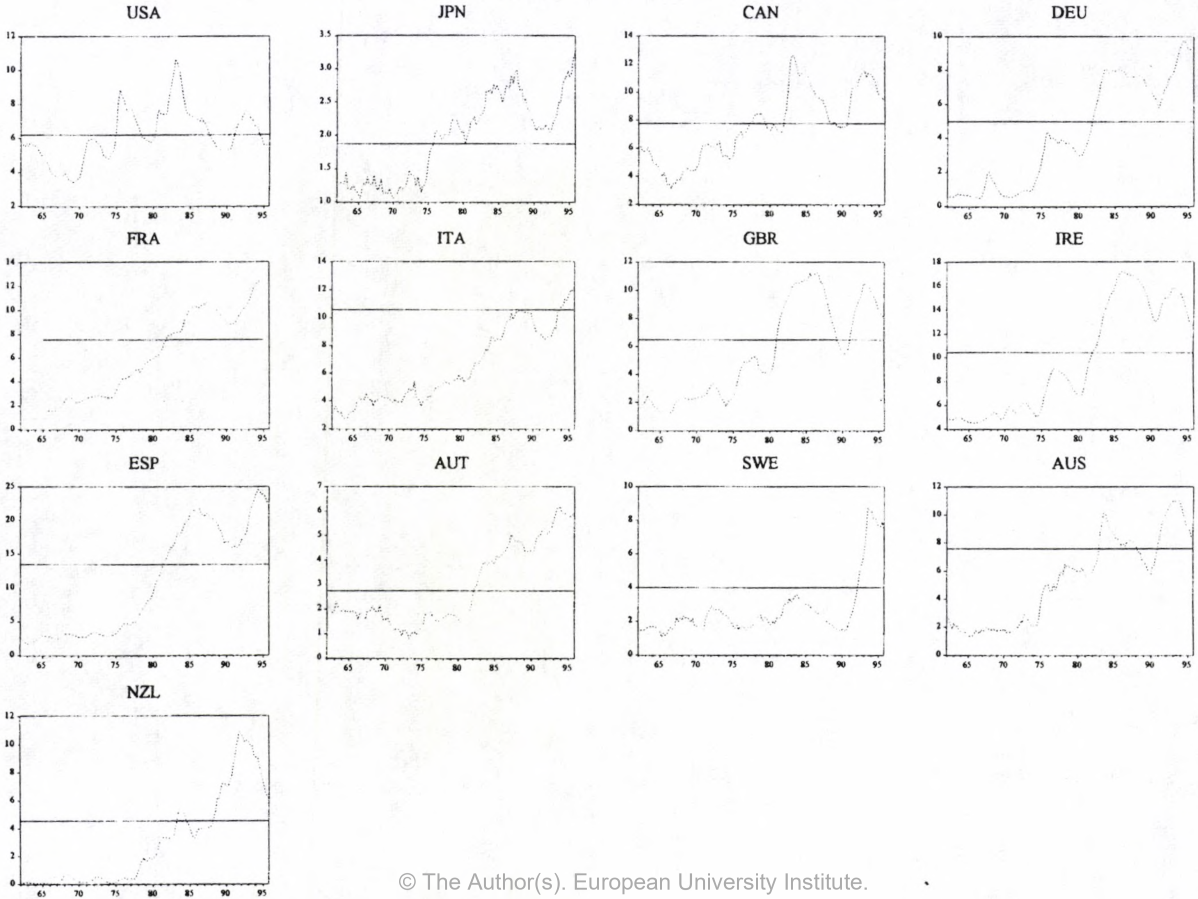


CHART 2: SCATTER PLOTS $\Delta^2 P_t$ AGAINST $U_{t-1}-U^*$ USING CONSTANT NAIRUs

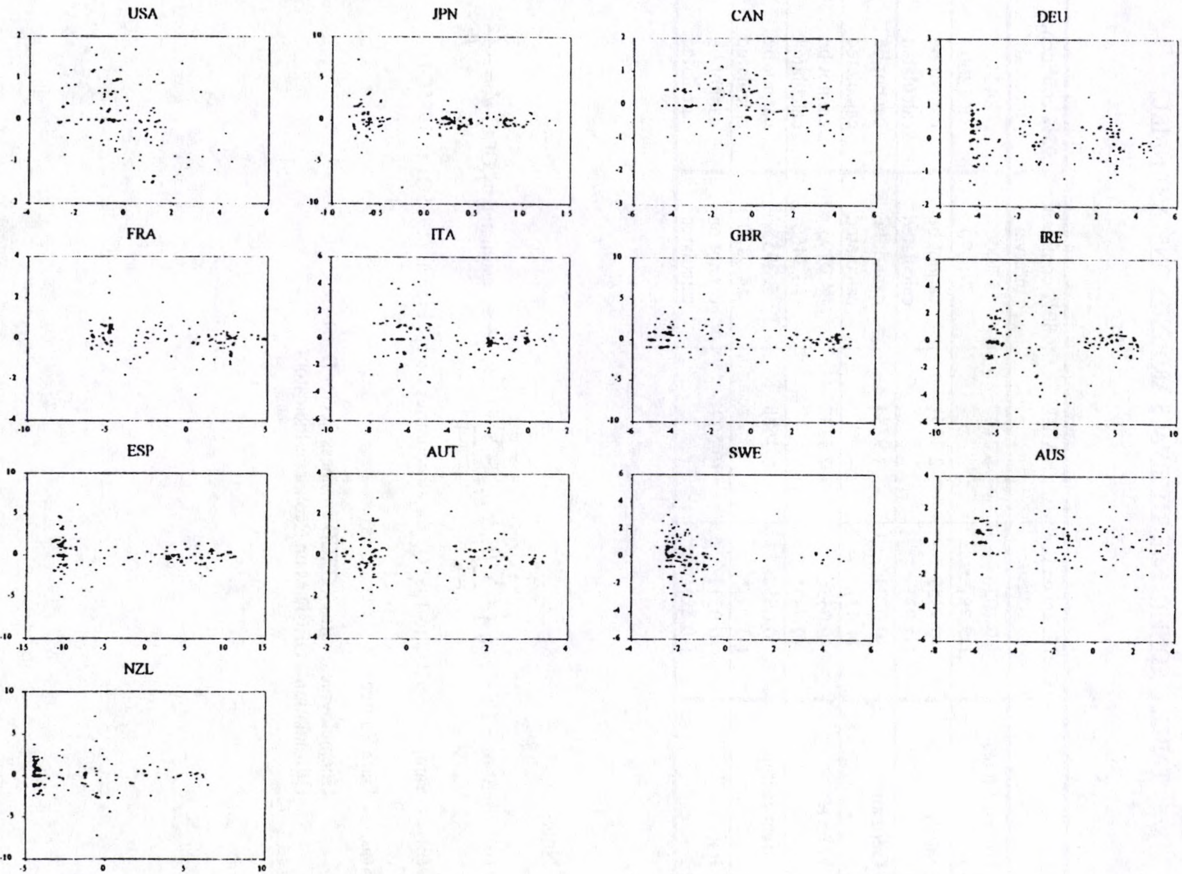


TABLE 1: CONFIDENCE INTERVALS AROUND CONSTANT NAIRUs

	Coefficient on U_{t-1} and t-statistic	NAIRU	80% confidence interval	95% confidence interval
United States	-0.1026 (-2.75)**	6.2107	5.3000 7.1690	4.4240 8.1200
Japan	-0.3352 (-1.27)	2.3051	cannot be calculated	cannot be calculated
Germany	-0.0221 (1.43)	4.9784	cannot be calculated	cannot be calculated
France	-0.0336 (2.21)*	7.5332	4.0295 16.3460	cannot be calculated
Great Britain	-0.0652 (-1.97)*	6.4688	2.8955 14.5820	cannot be calculated
Italy	-0.0311 (-0.82)	10.5691	cannot be calculated	cannot be calculated

Notes:

(i) $\Delta^2 p_t = \beta_0 + \gamma_1 u_{t-1} + \sum_{i=1}^{4} \beta_{1i} \Delta^2 p_{t-i} + \sum_{i=1}^{4} \gamma_{2i} \Delta u_{t-i} + \epsilon_t$ estimated by OLS; $u^* = -\frac{\hat{\gamma}_1}{\hat{\beta}_0}$.

(ii) Sample: 1962Q2 to 1995Q3 for all countries except France (1965Q1 to 1995Q1)

(iii) Data Sources:

Unemployment rates - OECD Business Sector Database
CPI inflation - OECD Main Economic Indicators.

SUMMARY CONSTANT NAIRU SPECIFICATION

	Estimated Constant NAIRU	Coefficient on U_{t-1} and t-statistic	Joint Significance of $\Sigma_i\beta_{1i}\Delta^2P_{t-1}$	Joint Significance of γ_1U_{t-1} and $\Sigma_i\gamma_{2i}\Delta U_{t-i}$
USA	6.2107	-0.1026 (2.75)**	$F(4,125) =$ 10.678**	$F(4,125) =$ 7.673**
JPN	1.8756	-0.1364 (0.76)	$F(4,125) =$ 12.161**	$F(4,125) =$ 3.150*
CAN	7.7691	-0.0632 (2.76)**	$F(4,125) =$ 10.467**	$F(4,125) =$ 4.405**
DEU	4.9784	-0.02211 (1.43)	$F(4,125) =$ 8.185**	$F(4,125) =$ 1.684
FRA	7.5332	-0.03602 (2.21)*	$F(4,108) =$ 13.222**	$F(4,108) =$ 2.431*
ITA	10.5691	-0.03110 (0.82)	$F(4,125) =$ 18.750**	$F(4,125) =$ 3.034*
GBR	6.4688	-0.06520 (1.97)*	$F(4,125) =$ 10.829**	$F(4,125) =$ 4.041**
IRE	10.4518	-0.05962 (1.95)	$F(4,125) =$ 8.411**	$F(4,125) =$ 1.877
ESP	13.4428	-0.02690 (1.73)	$F(4,125) =$ 14.298**	$F(4,125) =$ 1.349
AUT	2.7432	-0.02836 (0.63)	$F(4,125) =$ 4.568**	$F(4,125) =$ 0.361
SWE	4.0336	-0.03630 (0.60)	$F(4,125) =$ 16.279**	$F(4,125) =$ 2.448*
AUS	7.5938	-0.03340 (1.25)	$F(4,125) =$ 9.124**	$F(4,125) =$ 4.731**
NZL	4.5527	-0.06394 (1.79)	$F(4,125) =$ 12.753**	$F(4,125) =$ 5.268**

Notes: ** denotes zero restriction(s) rejected at 1% significance level or less; * denotes zero restriction(s) rejected at 5% significance level or less.

CHART 3: UNEMPLOYMENT RATES AND CUBIC SPLINE NAIRUs

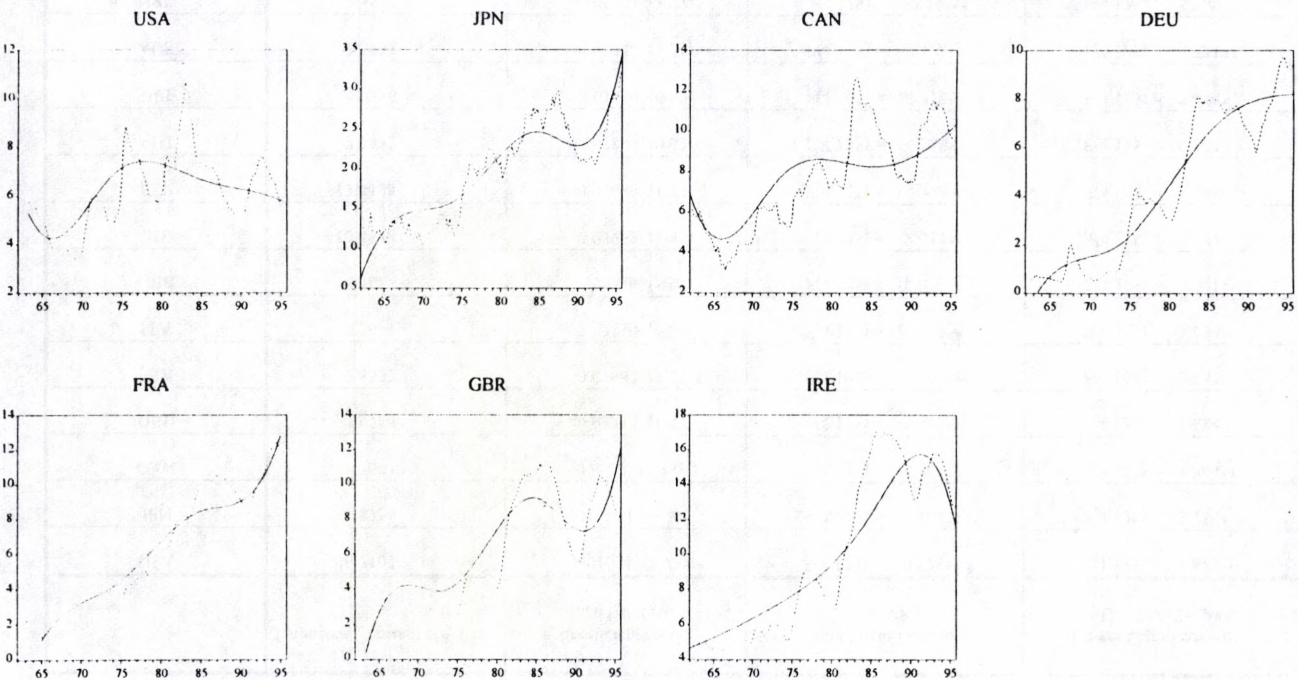


CHART4: SCATTER PLOTS $\Delta^2 P_t$ AGAINST $U_{t-1}-U^*_{t-1}$ USING CUBIC SPLINE NAIRUs

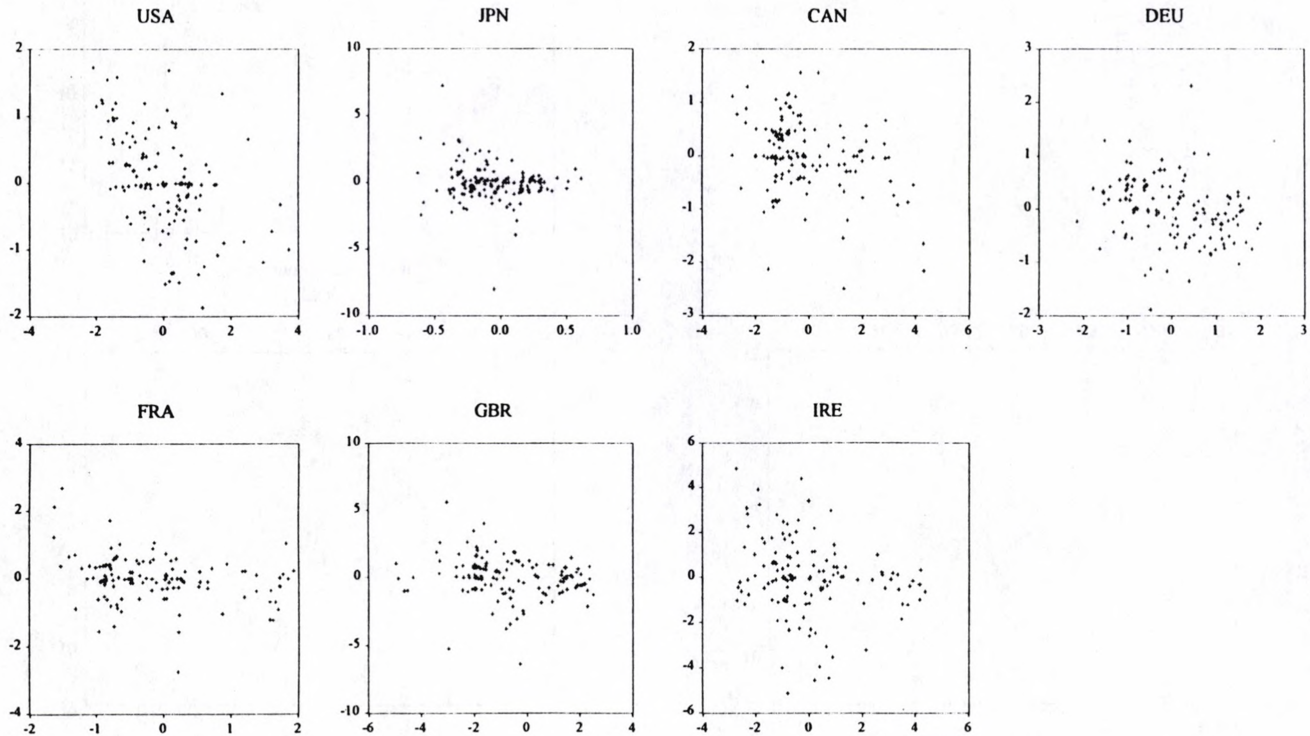
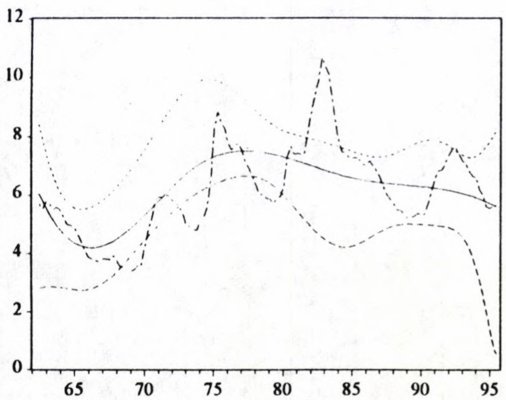
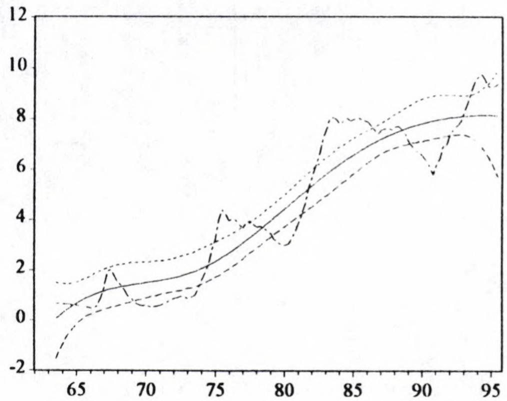


CHART 5: CONFIDENCE INTERVALS AROUND CUBIC SPLINE NAIRUs

USA
95% confidence interval



DEU
95% confidence interval



FRA
80% confidence interval

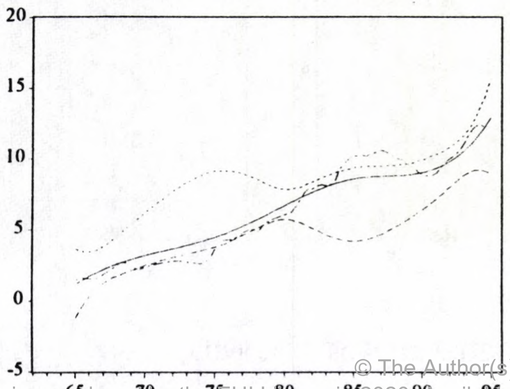


TABLE 2: CONFIDENCE INTERVALS AROUND SPLINE NAIRUs

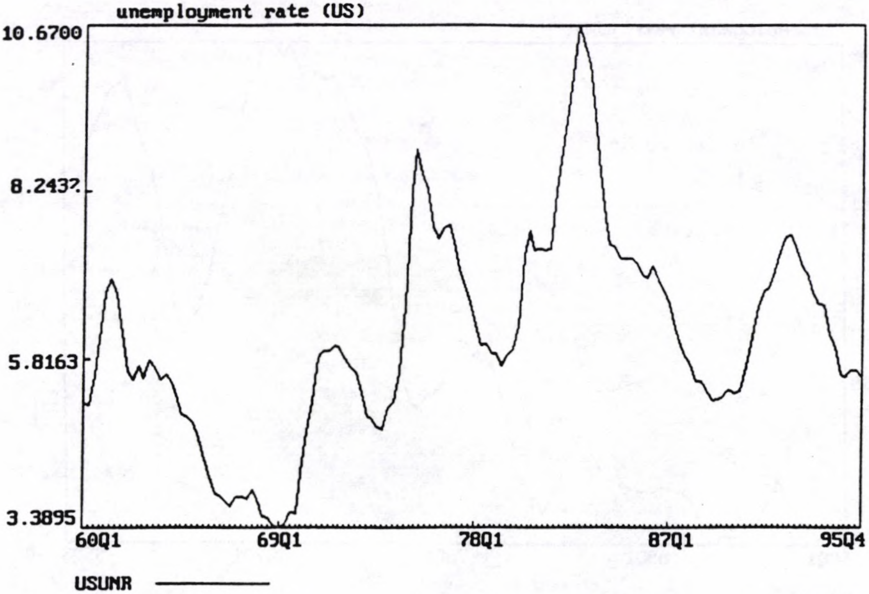
	ACTUAL UNEMPLOYMENT u_t	NAIRU 1990.1	80% CONFIDENCE INTERVALS	95% CONFIDENCE INTERVALS
USA	5.30	6.28		5.00 7.83
DEU	6.53	7.82		7.12 8.80
FRA	8.93	9.04	6.41 9.95	

SUMMARY CUBIC SPLINE NAIRU SPECIFICATION

	Estimated NAIRU in 1990:1	Coefficient on U_{t-1} and t-statistic	Joint Significance of Spline Regressors	Joint Significance of U_{t-1} and Spline Regressors
USA	6.2796	-0.2643 (3.50)**	F(5,120) = 6.196**	F(6,120) = 3.1852**
JPN	2.2906	-0.8475 (1.52)	F(5,120) = 0.963	F(6,120) = 0.957
CAN	8.6816	-0.1500 (2.98)**	F(5,122) = 1.437	F(6,122) = 2.858**
DEU	7.8246	-0.3071 (5.49)**	F(5,118) = 6.800**	F(6,118) = 6.613**
FRA	9.0375	-0.2278 (2.07)*	F(5,108) = 1.471	F(6,108) = 2.331**
GBR	7.4400	-0.1109 (1.72)	F(5,116) = 0.719	F(6,116) = 1.017
IRE	15.5498	-0.3434 (3.28)**	F(5,126) = 2.215	F(6,126) = 3.159**

Notes: ** denotes zero restriction(s) rejected at 1% significance level or less; * denotes zero restriction(s) rejected at 5% significance level or less.

CHART 6 : UNEMLOYMENT AND ITS HYSTERESIS INDEX



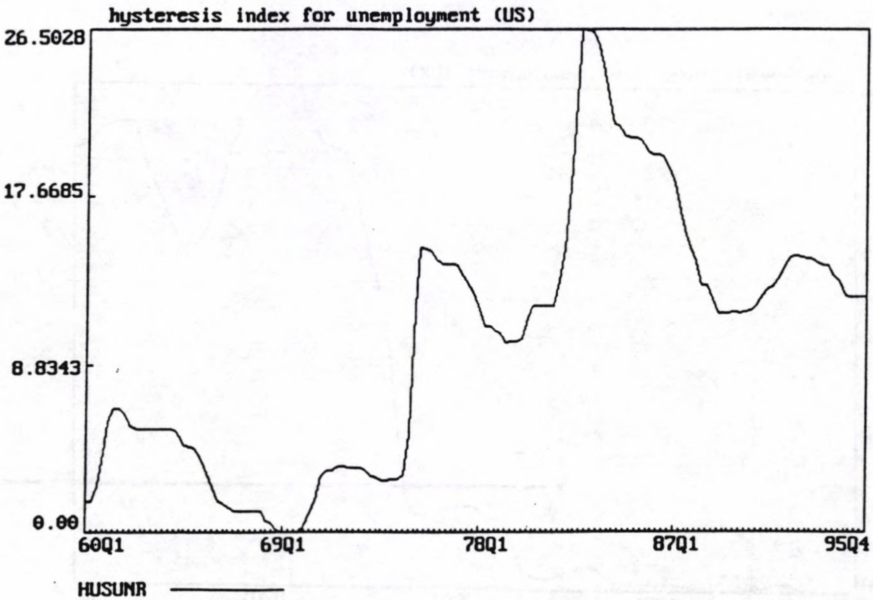
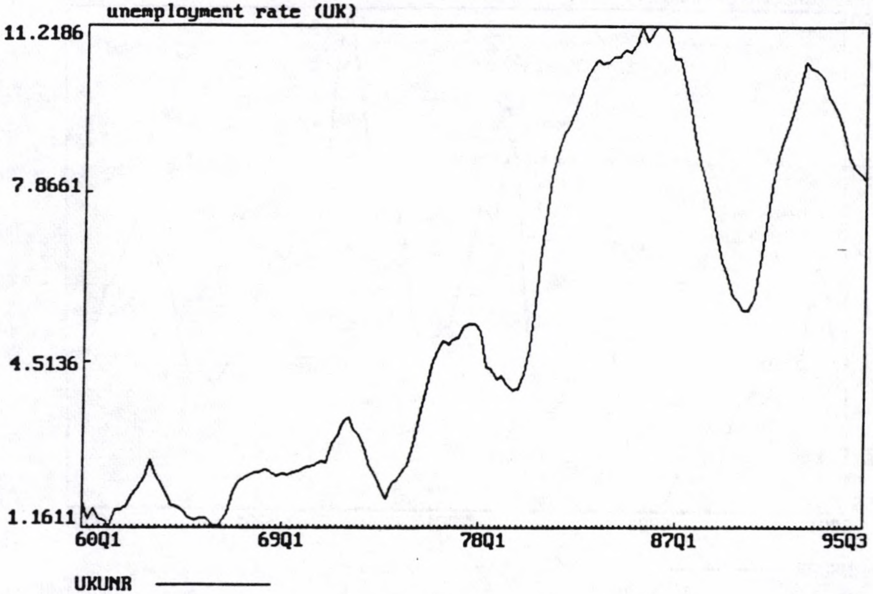
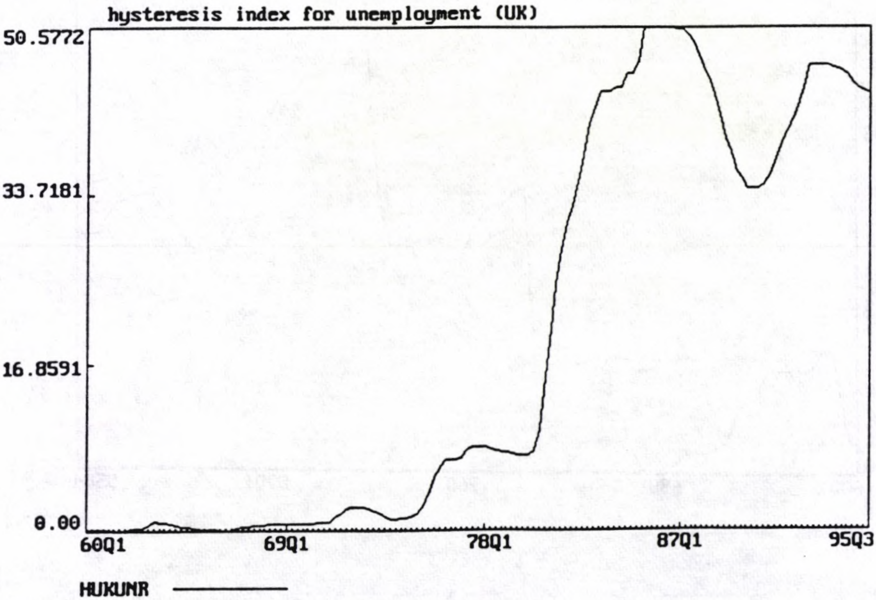


CHART 6 : UNEMPLOYMENT AND ITS HYSTERESIS INDEX





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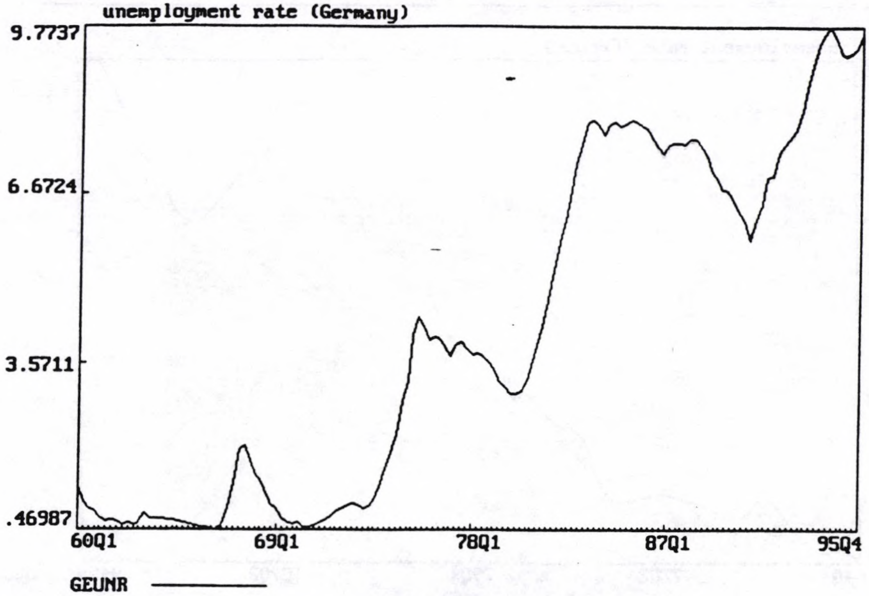

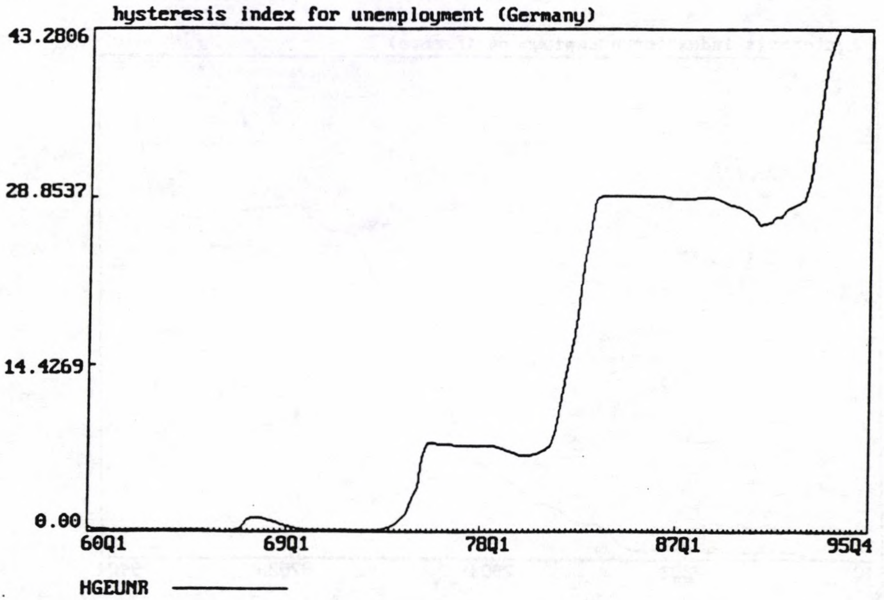

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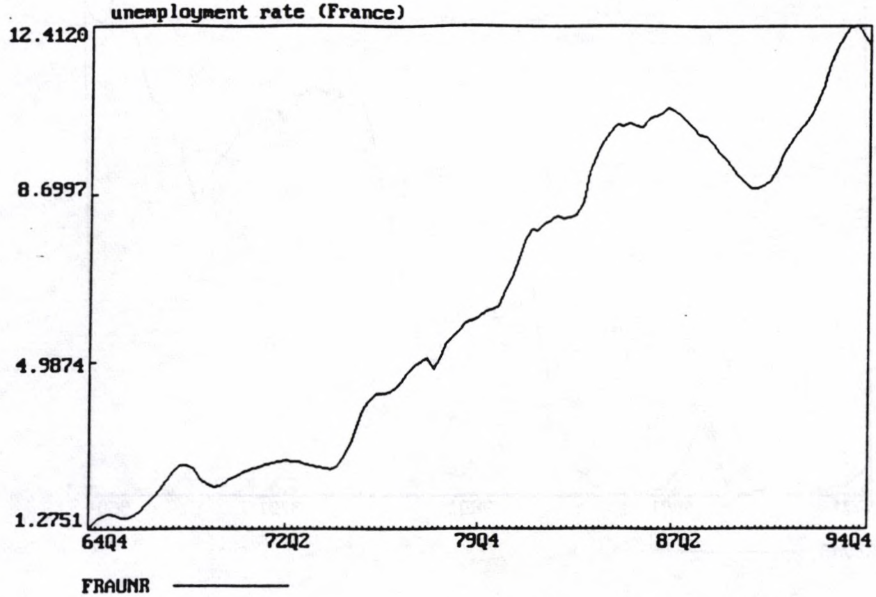

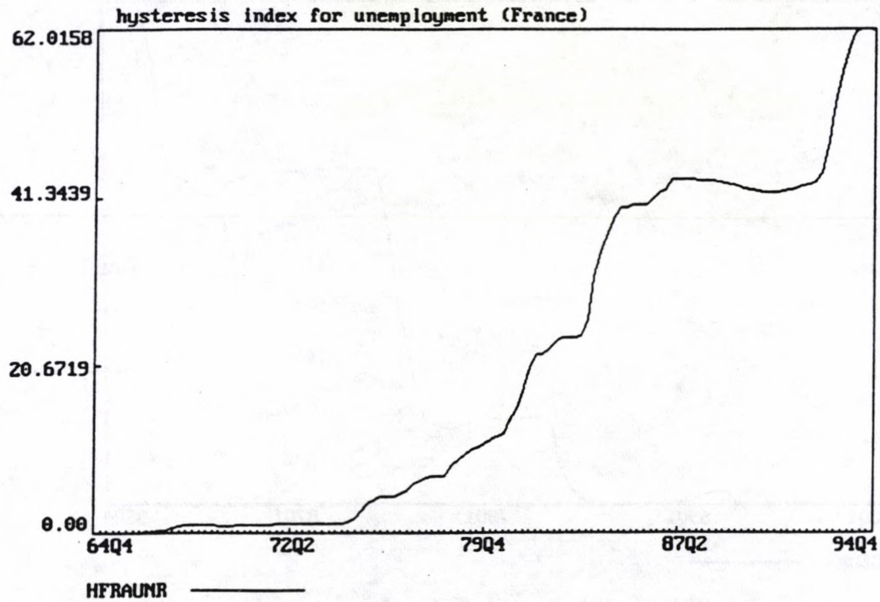

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